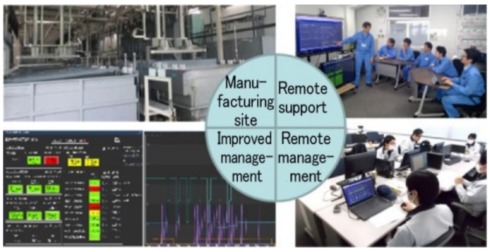
Smart Factory Solution for Surface Treatment of Aircraft Parts



Contact Office

Aero Structure Division, Commercial Aviation Systems

Service Engineering Department, Research & Innovation Center

The surface treatment of aircraft parts is controlled by setting reference values for various control parameters in order to maintain the performance and quality of treatment in the manufacturing process. To set these reference values, treatment techniques based on knowledge and experience, skilled chemical analysis techniques required for treatment liquid concentration control and treatment performance control abilities based on the treatment techniques and treatment liquid concentration control are required. Skilled engineers with these techniques have been required conventionally, but due to the decrease in the number of such engineers as a result of the aging of the population of skilled workers, there are concerns about the techniques transfer and stable parts production for future plant operation.

With the background described above, in order to realize appropriate treatment performance and treatment liquid concentration control in a timely manner without relying on skilled human resources, we have developed an in-line analyzer for special surface treatment liquid solutions. We have also built an innovative surface treatment management technology (smart factory) equipped with an IoT system that enables remote monitoring of continuously obtained treatment liquid concentration on the Web and makes time-series analysis possible.

This report introduces an application example of the smart factory.

1. Features and issues of surface treatment of aircraft parts

Since aircraft are used for decades under harsh environmental conditions (-50°C to +250°C, 0.2 to 1.0 atm), the surface treatment of aircraft parts must have a high corrosion resistance and is subject to strict control standards. The evaluation of the corrosion resistance cannot be checked as a product, so the quality is guaranteed by controlling the manufacturing process with indirect parameters such as the components and concentration of the surface treatment liquid and the treatment temperature and time.

However, in the case of the current manufacturing process management, it takes several days to several weeks from the preparation of a specimen for testing the composition and concentration of the treatment liquid and the corrosion resistance of the treatment to the acquisition of the test results, so there are problems such as that if a quality abnormality is detected late and corrosion resistance control standards are not met resulting in nonconformity, the treatment cannot be used for products, which affects the subsequent manufacturing processes.

As a method for improving the speed of quality abnormality detection, it is effective to control the liquid concentration with an in-line analyzer attached to the surface treatment equipment. However, it is difficult for commercially available in-line (automatic) analyzers to be used for the analysis of complex special solutions containing both high-concentration components and impurities used for the treatment of aircraft parts.

In addition, the parameters for manufacturing process management are controlled by reference values. However, to set these reference values, treatment techniques based on knowledge and experience, skilled chemical analysis techniques required for treatment liquid concentration control and treatment performance control ability based on the treatment techniques and treatment liquid concentration control are required. Skilled engineers with these techniques have been required conventionally, but due to the decrease in the number of such engineers as a result of the aging of the population of skilled workers, there are concerns about the techniques transfer and stable parts production.

Furthermore, the expiration date and replacement frequency of surface treatment liquids are often determined based on past achievements and experience that workers possess. Therefore, by transforming these achievements and experience into data, both costs for treatment liquid management (expiration date and replacement) and industrial waste can be reduced.

2. Technology application process

In response to features and issues of surface treatment of aircraft parts as described above, we aimed to build a monitoring system that can perform real-time correlation analysis of all process parameters related to surface treatment including liquid components. We also targeted building a surface treatment liquid management system that does not depend on human resources instead of the conventional liquid management, which relied on the ability and past experience of skilled workers, by incorporating the ability and experience of skilled workers into the control value setting and utilizing AI (**Figure 1**).

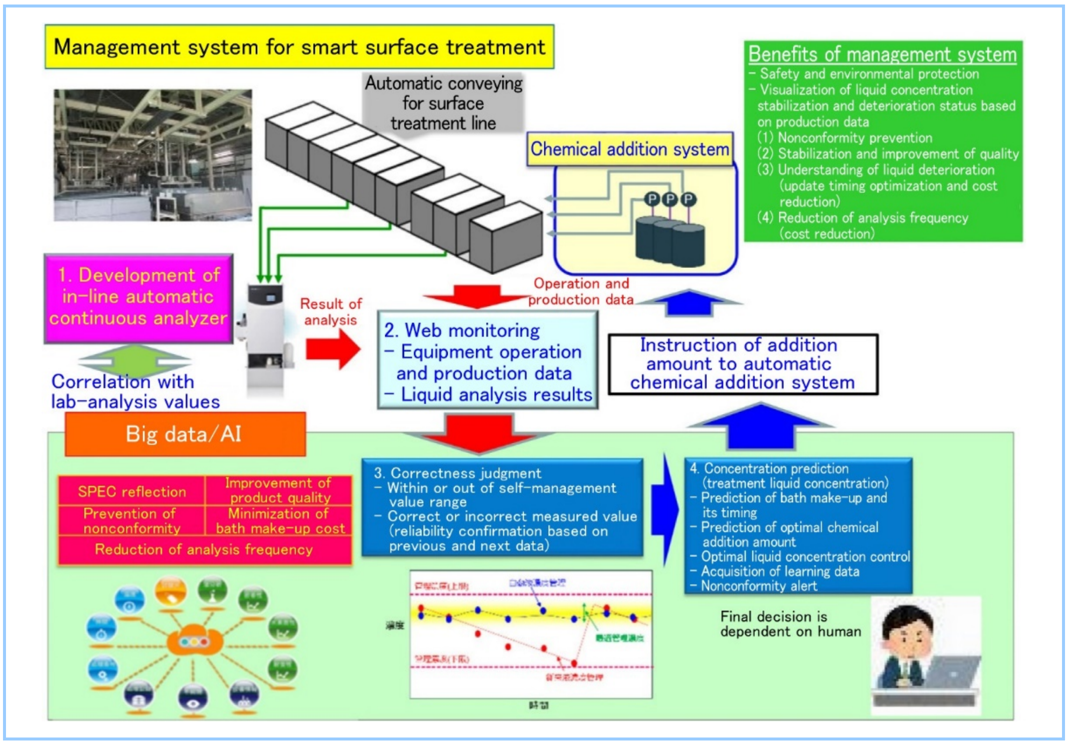


Figure 1 Management system for smart surface treatment

The specific application process is as follows.

(1) Development of in-line automatic continuous analyzer

Commercially available analyzers cannot be applied as-is to the analysis of complex special solutions containing both high-concentration components and impurities used for the treatment of aircraft parts. In order to solve this problem, we have developed an automatic analysis technology that automatizes liquid sampling, dilution and concentration detection and enables continuous analysis. We have also built an in-line automatic continuous analyzer that can check the concentration of surface treatment liquid components in real time at the installation site of a surface treatment line and can be remotely monitored by transferring the analysis results on the Web.

(2) Transforming process parameters into data and Web monitoring

For the purpose of stabilizing quality, improving treatment performance and managing surface treatment liquids such as setting the replacement frequency of surface treatment liquids, we have selected items that require monitoring (temperature, flow rate, etc.) and installed the sensors required for operation data acquisition. We have built an IoT system that can monitor a large amount of data acquired by sensors in real time from a remote location on the Web and can perform correlation analysis. The monitoring screen can be easily customized by hand to meet changing needs, enabling advanced management of surface treatment liquids.

(3) Sophistication of management utilizing big data

Optimal treatment conditions can be set based on the aforementioned in-line automatic continuous analysis concentration and process parameters. By realizing real-time manufacturing process management, rapid abnormal value detection and optimal chemical concentration control were realized.

(4) Realization of automatizing human-independent management using AI (future development)

We have built a foundation for AI utilization with big data. In the future, through the use of AI, we will build an automatic chemical addition system by managing optimal treatment conditions according to the manufacturing situation and predicting the liquid concentration and will promote the transition to innovative, human-independent manufacturing process management with the aim of achieving optimal liquid management and improved treatment performance.

3. Introduction of surface treatment management system

This chapter gives an example of introducing the surface treatment management system we built to the automatic surface treatment line of a remote partner (joint venture) that has similar issues and applying it to the production process.

As the analysis targets to which the in-line automatic continuous analyzer is applied, the treatment liquid types and liquid components shown in **Table 1** were selected in consideration of the fact that their quality nonconformities have a large range of influence at the time of occurrence, they are highly serious and frequently occur. The "analysis interval" in this table shows the shortest time from the automatic sampling of the treatment liquid to the acquisition of the analysis results. The shorter this time, the faster that feedback to the manufacturing process management can be provided.

Table 1 Development targets of in-line automatic continuous analyzer

Target liquid	Target component item	Analysis interval	
		Conventional	After system introduction
Supply water (pure water)	Silica	About 10 days	Every 45 minutes
Washing water	pH	About 10 days	Every 1 hour
Washing water	Electrical conductivity	About 10 days	Every 1 hour
Washing water	Hexavalent chromium	About 10 days	Every 2 hours
Washing water	Trivalent chromium	About 10 days	Every 2 hours
Washing water	Nitric acid	About 10 days	Every 2 hours
Anodic oxidation treatment liquid	Boric acid	About 10 days	Every 10 minutes
Anodic oxidation treatment liquid	Sulfuric acid	About 10 days	Every 10 minutes
Alkaline cleaning liquid	Alkalinity	About 10 days	Every 3 hours

As shown in **Figure 2**, it took 10 days to check the treatment liquid concentration conventionally, but the introduction of the in-line automatic continuous analyzer made it possible to check the analytical value in seconds to tens of minutes and to check the concentration on site. As a result, visualization of the liquid properties that change from moment to moment during production has been realized. As shown in **Figure 3**, the introduction of the automatic continuous analyzer made it possible to acquire data at short intervals, resulting in the improvement of analysis accuracy and speeding up and facilitating cause analysis at the time of abnormality detection.

The actual monitoring screen is described below. **Figure 4** shows a screen displaying the results of analyzing the liquid component concentration in each treatment liquid with the in-line automatic continuous analyzer in real time. The values indicated are the latest analytical values sent from the analyzer and are automatically updated when results are detected. The color of a value frame indicates the management status: green, yellow and red means "within the management value range," "near management limit" and "out of management value range", respectively, which makes it possible to check the current state of the surface treatment liquid at a glance.

Figure 5 is a graph in which the water quality and operating state of the water washing bath are plotted. The electrical conductivity (one of the indexes for evaluating the degree of contamination of a water washing bath), water supply flow rate and product treatment timing are represented on the vertical axis and the time is represented on the horizontal axis. By evaluating a plurality of process parameters in chronological order in this way, it is possible to determine, for example, whether the water supply flow rate is sufficient or too high to maintain the water washing bath in a normal state. It has also become possible to examine and evaluate the conditions for the treatment bath operation and concentration control in order to maintain and improve the treatment performance while considering the minimum necessary cost.

The following results can be expected by introducing the surface treatment liquid management system introduced above.

(1) It was made possible to realize timely treatment liquid management and reduce the occurrence of nonconforming products and the impact on subsequent manufacturing processes.

(2) By incorporating various process parameters (production information, equipment information and liquid component analysis results) in a timely manner, production stabilization with optimal treatment condition management and cost reduction (manufacturing cost reduction of 10%) with treatment liquid usage period (life) prediction were realized, which also contributed to the achievement of SDGs by minimizing waste liquid and wastewater.

(3) By quantifying the management level, difficulty in the transfer of techniques and the impact of the retirement of experienced human resources on production were resolved.

(4) For setting up a new surface treatment base, surface treatment liquid management from a remote site was realized, which greatly contributed to the start-up of vertical stable production.

(5) Online management and technical support from a remote site has become possible even when no skilled human resources are present on site.

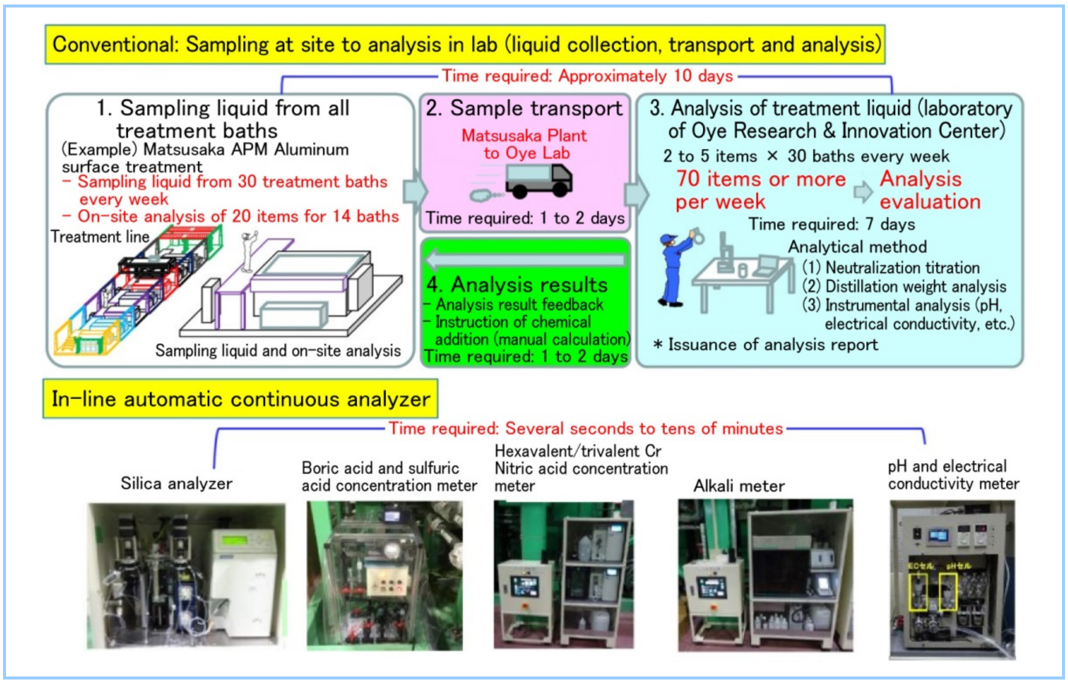
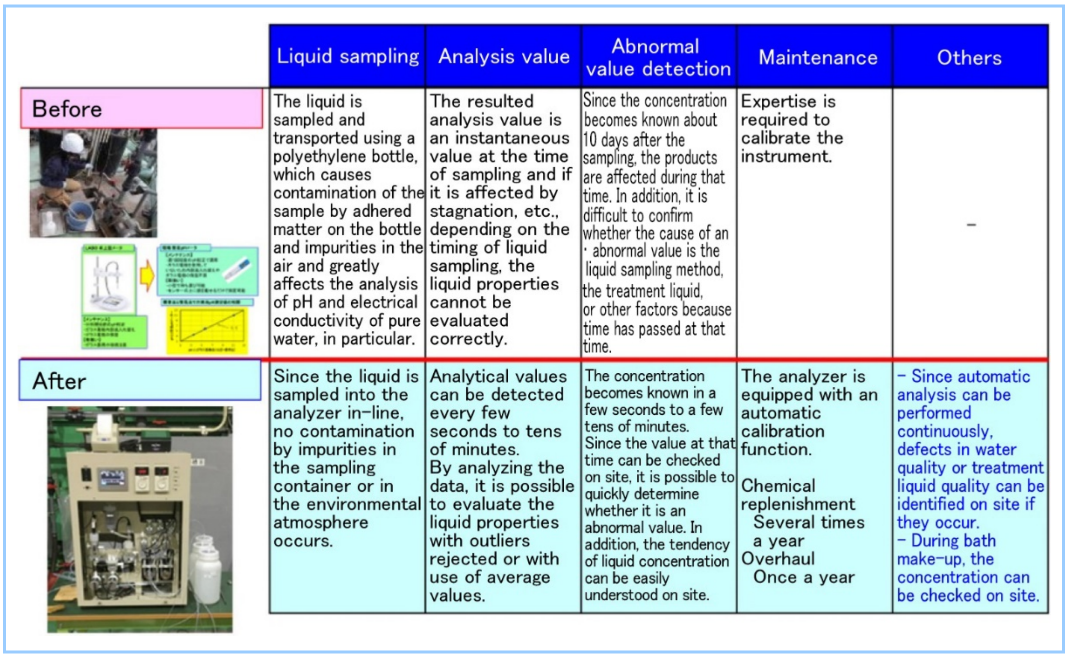


Figure 2 Development results 1 of in-line automatic continuous analyzer



	Liquid sampling	Analysis value	Abnormal value detection	Maintenance	Others
Before	The liquid is sampled and transported using a polyethylene bottle, which causes contamination of the sample by adhered matter on the bottle and impurities in the air and greatly affects the analysis of pH and electrical conductivity of pure water, in particular.	The resulted analysis value is an instantaneous value at the time of sampling and if it is affected by stagnation, etc., depending on the timing of liquid sampling, the liquid properties cannot be evaluated correctly.	Since the concentration becomes known about 10 days after the sampling, the products are affected during that time. In addition, it is difficult to confirm whether the cause of an · abnormal value is the liquid sampling method, the treatment liquid, or other factors because time has passed at that time.	Expertise is required to calibrate the instrument.	-
After	Since the liquid is sampled into the analyzer in-line, no contamination by impurities in the sampling container or in the environmental atmosphere occurs.	Analytical values can be detected every few seconds to tens of minutes. By analyzing the data, it is possible to evaluate the liquid properties with outliers rejected or with use of average values.	The concentration becomes known in a few seconds to a few tens of minutes. Since the value at that time can be checked on site, it is possible to quickly determine whether it is an abnormal value. In addition, the tendency of liquid concentration can be easily understood on site.	The analyzer is equipped with an automatic calibration function. Chemical replenishment Several times a year Overhaul Once a year	- Since automatic analysis can be performed continuously, defects in water quality or treatment liquid quality can be identified on site if they occur. - During bath make-up, the concentration can be checked on site.

Figure 3 Development results 2 of in-line automatic continuous analyzer

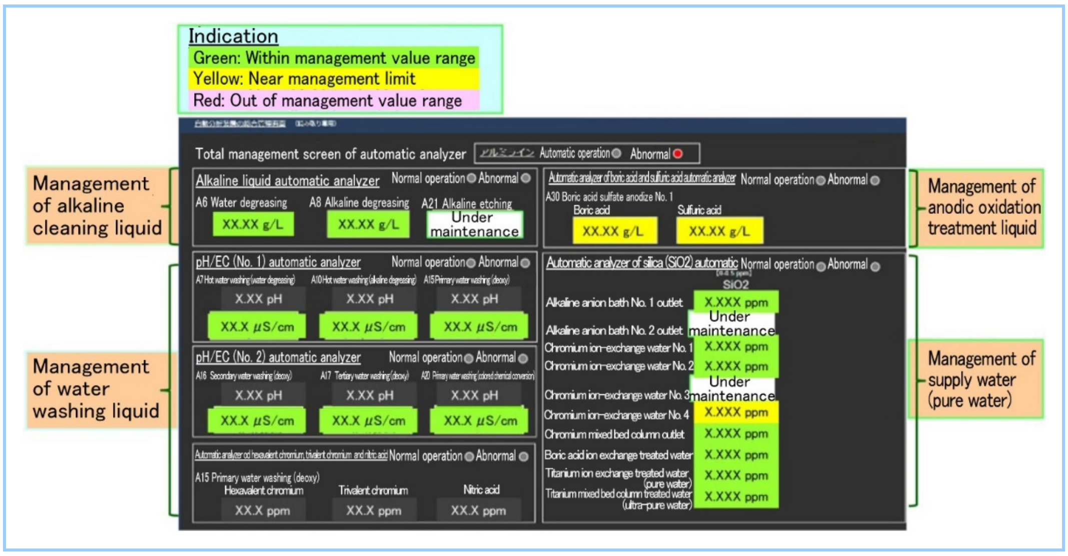


Figure 4 Monitoring screen of in-line automatic continuous analysis value

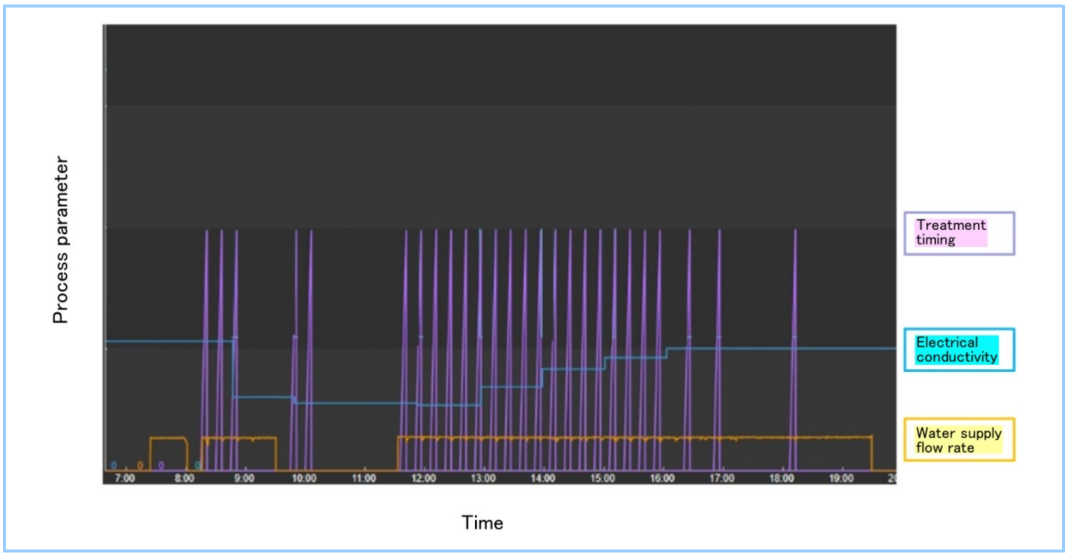


Figure 5 Water washing bath monitoring screen (correlation analysis)

4. Future prospects

Currently, we are proceeding with the quantification and sharing of knowledge on surface treatment liquid management by incorporating the experience and ability of skilled workers into the control value setting. In the future, we will focus on the shift to a manufacturing process that does not rely on conventional human-related factors with the aim of utilizing AI based on big data to realize optimal liquid management through the management of conforming product conditions and the prediction of liquid concentration according to the manufacturing status.